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Prone to suffering geometrical nonlinear deformations (including large-deflection, snap-through, and post-buckling) as a consequence of external excitations and operational loadings, highly flexible composite structures have been frequently utilized in spacecraft science; applications include, but are not limited to, deployable satellites' instrumentation, antennas, and solar arrays. Therefore, accurate predictions of their in-service nonlinear static response in the geometrically nonlinear scenario are of paramount importance for design and failure evaluation.

In this work, a unified formulation of geometrically nonlinear refined shell theory based on the Carrera Unified Formulation (CUF) and a total Lagrangian approach [1-3] is developed to investigate the geometrical nonlinear response of metallic shells in the orthogonal parallel curvilinear coordinate system. Accordingly, various kinematics of two-dimensional shell structures are formulated via an appropriate index notation and an arbitrary expansion function of the generalized variables in the thickness direction, leading to lower- to higher-order shell models with only pure displacement variables based on the Lagrange polynomial expansions. Furthermore, the principle of virtual work and a finite element approximation are exploited to straightforwardly and easily formulate the nonlinear governing equations. Taking into account the three-dimensional full Green-Lagrange strain components, the secant and tangent stiffness matrices of the unified shell element are presented in terms of the fundamental nuclei, which are independent of the theory approximation order. The Newton-Raphson linearization scheme combined with a path-following method based on the arc-length constraint is utilized to solve the geometrically nonlinear problem. Numerical simulations and comparisons of the present results with those found in the literature for typical benchmark problems (involving pull-out of an open-ended cylindrical shell, pinched semi-cylindrical shell, cylindrical/spherical panels under point load), are found to be excellent and demonstrate the capabilities of the developed CUF shell model to accurately predict the nonlinear equilibrium curves as well as the stress distributions.

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